ACTS Propagation Campaign

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Abstract

Because of a shortage of propagation data in satellite links, the existing Ka-band propagation models are inadequate for accurately predicting tropospheric-induced anomalies of the slant path. To remedy this shortcoming, NASA has implemented the Advanced Communications Technology Satellite (ACTS) Propagation Campaign. This is a campaign of experimental and analytical efforts using the ACTS satellite as the main vehicle for field measurements. The data-collection phase of the campaign began in fall 1993 and will last for at least two years.

The overall goal of this campaign is to expand the state of knowledge about all important Ka-band frequency impairments to Earth-space communications including rain attenuation, the effects of clouds, clear air, and tropospheric scintillation. Dynamic effects such as fade duration and fade rates are of particular interest to the design of compensation techniques based on power control and coding. Equally important is providing information critical to the design of efficient resource reserve strategies (power, coding, time pool) for future Ka-band satellites. Rain rate and sky noise temperature measurements will allow researchers to develop high-resolution rain climate maps for predicting of propagation effects in those parts of the country that lack propagation data.

This paper reviews the ACTS Propagation Campaign and presents campaign elements, logistics, and schedule. Several types of experiments including fixed, mobile, and power control efforts are described.

1. Introduction

Radiowave propagation is an integral part of satellite signal transmission. A good understanding and prediction of propagation effects is an essential ingredient for successful planning of Earth/space communication systems. Although theoretical skills are useful in gaining information on radio wave propagation, empirical techniques are needed to obtain insight into propagation peculiarities of satellite links. In fact, most of the prior literature enjoy a balance of experiment with theory.

The best sources of information for propagation-effects prediction are NASA propagation handbooks and ITU-R recommendations [1 - 3]. The main causes of impairment at Ka-band frequencies stem from tropospheric effects, i.e., gaseous and rain attenuation, scintillation, depolarization, etc., with attenuation being the dominant factor. Lack of adequate data, however, prevents us from developing prediction models that are sufficiently accurate for most regions of the world.

A good example of how the shortage of data impedes our ability to predict propagation effects is a rain climate map used in rain attenuation prediction. Due to the scarcity of data, climate maps are crude and in need of revision. This particular shortcoming, however, has not gone unnoticed by the international community and measures are being taken to improve both the format and the content of such maps.

There are many areas needing attention and, as more data become available, our ability to estimate propagation impairments improves. Recently the European Olympus campaign provided a good opportunity for the international propagation community to improve Ku-and Ka-band models. Most of data came from Europe with only one U. S. site contributing [4]. The ACTS propagation campaign complements the Olympus endeavor by carrying out similar experiments in North America, thus substantially increasing our knowledge of radio wave propagation effects.

2. ACTS Campaign Objectives and Approach

Table 1 lists the objectives of the ACTS propagation campaign. The table also shows the approach adopted to reach each objective.

Table 1. ACTS Propagation Campaign Objectives and Approach

OBJECTIVE	APPROACH
1 Provide a base of 20/30-GHz slant-path propagation data	Make long-term beacon measurements at multiple sites
2 Improve the existing rain-climate maps	Make long-term meteorological measurements at geographically diverse sites
3 Improve the existing rain attenuation models	Use a team of propagation experts to collect and analyze data
4 Develop frequency-scaling models	Make dual frequency measurements
5 Study large-baseline diversity effects	Collect data at sites separated by hundreds of kilometers
6 Develop fade compensation algorithms	Collect first and second order statistics
7 Study scintillation effects	Collect data at adequate sampling rates
8 Characterize the mobile channel	Make mobile measurements
9 Archive and disseminate data	Use ACTS Propagation Data Center

Objectives 1 and 2 will be achieved by making beacon and meteorological measurements at a minimum of seven sites located in different rain climate zones in North America. These measurements will continue with little interruption for a period of at least two years with the possibility of extension to four years. These sites are equipped with dual-channel beacon receivers at 20 and 27 GHz, dual-channel

radiometers at approximately the same frequency, a rain gauge, and humidity and temperature sensors. The experimenters who collect data will collaborate with other researchers to develop rain climate maps and attenuation-prediction models (Objective 3). Objective 4 will be accomplished by analyzing the dual-frequency beacon and radiometric observations and correlating these measurements with meteorological data. Objective 5 will be achieved by the analysis of data collected from the seven sites. These sites are spaced many hundreds or thousands of kilometers apart. The cross correlation of data from all these sites is expected to reveal large-scale diversity effects, allowing a comprehensive evaluation of techniques used for satellite resource sharing by Earth stations scattered throughout the U.S.

Objective 6 will be accomplished by using the collected data from the seven sites to test fade-compensation schemes. There are also two experiments planned for direct evaluation of uplink power control technology using signals transmitted through the satellite. These trials include both stationary and mobile field measurements.

Scintillation information will be extracted from data collected at the seven sites. Subsequent data analysis will pave the road for the development of prediction models for tropospheric scintillation (Objective 7).

To achieve Objective 8, mobile measurements will be taken at 20 GHz to provide us with a database for mobile propagation effects in the Ka-band. These experiments will take place at different roads in the lower 48 states as well as Alaska. Some observations will be repeated in different seasons to study foliage attenuation effects.

Data archiving and dissemination will be performed by the ACTS Data Center at the University of Texas. This center will receive monthly propagation data from all the sites. The received data will be tested for validity and, if approved, will be archived. If a test fails, the experimenter will be notified immediately to prevent the collection of bad data. At the termination of the two-year campaign, all data collected from the seven sites will be stored on six CD-ROM disks for distribution to the propagation and satellite communications community, or whoever is interested in the data.

3. Propagation Terminals and Experiment Sites

The ACTS Propagation Campaign employs a variety of terminals for collecting propagation data. This set includes the ACTS Propagation Terminal (APT) delivered by NASA to the experimenters, a mobile propagation terminal, and a few others.

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3.1 The ACTS Propagation Terminal. The APT uses a small dual-frequency (20- and 27-GHz) antenna and a front end shared by the beacon and the total-power radiometer receivers. The RF front end enclosure is carefully temperature controlled to ensure radiometer stability. A simplified block diagram of the APT is shown in Figure 1. The salient features of the terminal are as follows:

- 1.2-m common antenna for both 20- and 27-GHz beacons
- Ortho-mode transducer (OMT) to separate the 20- and 27-GHz signals
- Preamplifiers followed by single downconversion to 70-MHz intermediate frequency (IF)
- Digital beacon receiver with 15-Hz detection bandwidth
- Total-power radiometers with sensitivity of 1 K
- PC-based data collection system

The output of the 70-MHz IF signal is split into two paths. In one path, the signal is further downconverted to 455 kHz. The 455-kHz signal drives the digital receiver. The digital receiver performs a fast Fourier transform (FFT) over 200 kHz during acquisition to locate the beacon signal. In the operational mode, a narrow band FFT is used to drive a frequency tracking loop. The detection bandwidth is 15 Hz. A major advantage of the digital receiver is that it acquires the signal in less than 3 seconds from any point within the 200-kHz bandwidth and reliably locks to the carrier component of the complex modulated beacon signal. If the signal is lost in a deep fade, it will be acquired as soon as the attenuation is less than about 25 dB.

The second path of the 70-MHz IF output signal feeds the radiometer. The radiometer measures the noise power over a 50-MHz bandwidth, Calibration is performed automatically at frequent intervals by switching a low-loss coaxial switch ahead of the mixer to the RF noise diode in series with an attenuator.

The PC-based Data Acquisition and Control System (DACS) consists of three major components: data acquisition and control hardware, personal computer, and DACS and ACTSVIEW software programs. The data acquisition and control hardware is located in the IF chassis and collects data from the beacon receivers, the radiometers, environmental instruments, and system temperature sensors. This hardware also controls the calibration of the radiometer channels. The PC hardware receives all data transmitted from DACS, logs the data to disk, and displays the collected data for user viewing. The PC is placed indoors, whereas the rest of the DACS is located outdoors in the IF chassis.

Figure 2 shows the APT. There are seven of these terminals installed at measurement sites as shown in Table 2. Although other fixed terminals will also be used to extend the range of data, the seven APTs constitute the backbone of the ACTS propagation campaign.

Table 2. ACTS Propagation Terminal Sites

LOCATION	ITU-R RAIN ZONE	tAT (North), Deg	LONG (West), Deg	AZ from North, Deg	PATH EL, Deg
Vancouver, BC	D	49	123	150.4	30
Ft. Collins, CO	E	40	105	172.7	43
Fairbanks, AL	c	65	148	129.3	9
Clarksburg, MD	K	39	077	213.5	39
Las Cruces, NM	M/E	32	107	167.8	51
Norman, OK	M	35	097	184.4	49
Tampa, FL	N	28	082	213.9	52

3.2 Mobile Propagation Terminal. The mobile receiver system is depicted in Figure 3, showing a microwave spectrum analyzer and frequency synthesizer at the heart of the RF subsystem. Other main functional components are the antenna tracker system, a low noise frequency downconverter, an IF stage with automatic frequency control (AFC), and a PC-based data acquisition system. Ancillary sensors give vehicle speed and direction.

The receiver uses an open-loop tracking system for maintaining satellite direction during field measurements. Two sites, Maryland and Alaska, have been selected for making the measurements. Depending on the success of these experiments, more sites may be included in this endeavor in the future. The salient features of the receiver are given in Table 3.

Table 3. Salient Features of the ACTS Mobile Propagation Terminal

FEATURE	VALUE
Signal frequency and polarization	19.9 GHz; Vertical
Antenna diameter, gain, and beamwidth	15 cm; 28 dBi; 6.8 deg
System noise temperature (nominal)	430 K

Beacon EIRP
    Maryland
    Alaska (Fairbanks)
	
	65 dBW
	56 dBW

Carrier-to-noise ratio (in 400 Hz)
    Maryland
    Alaska (Fairbanks)
	
	58 dBW
	47 dBW

3.3 Other Terminals   Propagation data may also be acquired from a host of ground stations employed in the ACTS communication and other experiments. Examples include the NASA ground station in Cleveland, Ohio, the network of ACTS Very Small

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Aperture Terminals (VSATs), and the ACTS Mobile Terminal at the Jet Propulsion Laboratory (JPL). The mobile terminal at JPL is a two-way communications terminal and should not be confused with the mobile propagation terminal mentioned earlier. Comsat Labs is planning a diversity test where the APT and a terminal provided by Comsat will be used together for the experiment. A similar experiment has also been proposed by Florida Atlantic University.

The NASA ground station in Cleveland will produce data similar to the APT with the exception of radiometric data because the NASA station is not equipped with radiometers. The VSATS receive only 20-GHz signals. Hence, they would neither produce 27-GHz beacon data nor radiometric data. It is hoped that data from as many stations as possible will be used to augment data from ACTS propagation experiments to increase the resolution of the resulting climate maps and rain fade models.

4. ACTS Propagation Data Center

The ACTS Propagation Data Center, or Data Center, is a key element of the ACTS propagation campaign. The Data Center will receive raw and preprocessed data from ACTS propagation experimenters every month. The received data will be checked for validity before being added to the data bank . Any faulty data will be flagged and immediately reported to the corresponding experimenter to prevent the collection of bad data. The responsibilities of the Data Center are follows:

• Data quality control
• Data archiving
• Data distribution and reporting
• Experimenter support

5. ACTS Propagation Studies Workshop (APSW)

The APSW is the main vehicle for making and revising plans for ACTS propagation experiments. The two-day workshop is held annually, usually in late fall, and it is attended by some forty experts in the fields of propagation and satellite communications. The participants come from universities, industry, and government organizations. The workshop is informally divided in two working groups: "systems" and "science." Four workshop meetings have already taken place, with the first one in November 1989 and the fifth is scheduled for November 30 — December 1, 1993. The APSW is also complemented by a miniworkshop that meets once a year in the spring in conjunction with the annual NASA Propagation Experimenters (NAPEX) meeting.

APSW I and II defined campaign objectives and APT requirements. APSW III defined the Data Center requirements and also introduced refinements to the APT architecture. APSW IV concentrated mainly on experimenter discussions and

familiarization of the experimenters with the APT. APSW V will discuss site operational issues and experiment plans.

6. Data Dissemination and Reporting

Information will be disseminated by individual experimenters, the Data Center, and researchers in academia and elsewhere. Each ACTS propagation experimenter group is expected to publish its own measurements and analysis results as soon as possible. In addition to this, the Data Center will publish a compendium of campaign results at the end of the experiment period. The preprocessed data will be available from the Data Center on CD-ROM disks.

These data can be obtained by any interested researcher in academia or industry for further investigation. It is expected that the result of such investigations will also become available to the user community.

The minimum requirements are to publish basic statistics on attenuation, fade duration, attenuation ratios at two frequencies, sky noise temperature, and rain rate. However, it is expected that the campaign will produce an array of prediction models and climatological maps, thereby addressing many of the Ka-band propagation needs of the satellite communications community [5].

7. Summary

The ACTS Propagation Campaign will greatly increase our knowledge of Ka-band (20/30 GHz) propagation effects in satellite links. The findings of the campaign will be used by system planners to develop new satellite communications systems and applications.

Although most of the campaign funding is supplied by NASA, industry is also contributing to this endeavor. The experimenter community consists of academia and industry.

8. Acknowledgment

8. References

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2 J. Goldhirsh and W. Vogel, Propagation *Effects for Land Mobile Satellite* Systems, NASA Reference Publication 1274, Feb. 1992.

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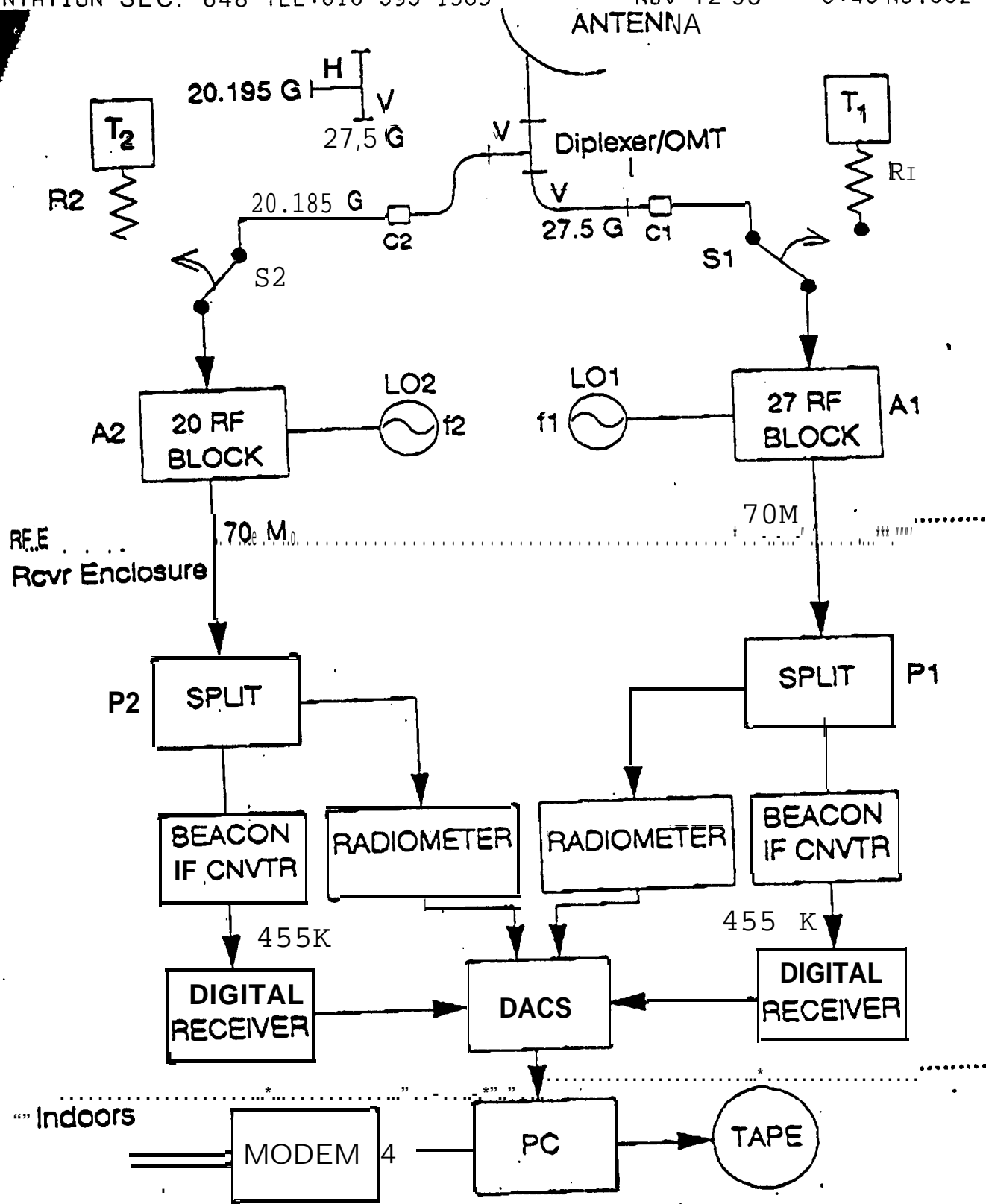
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Figure 1.
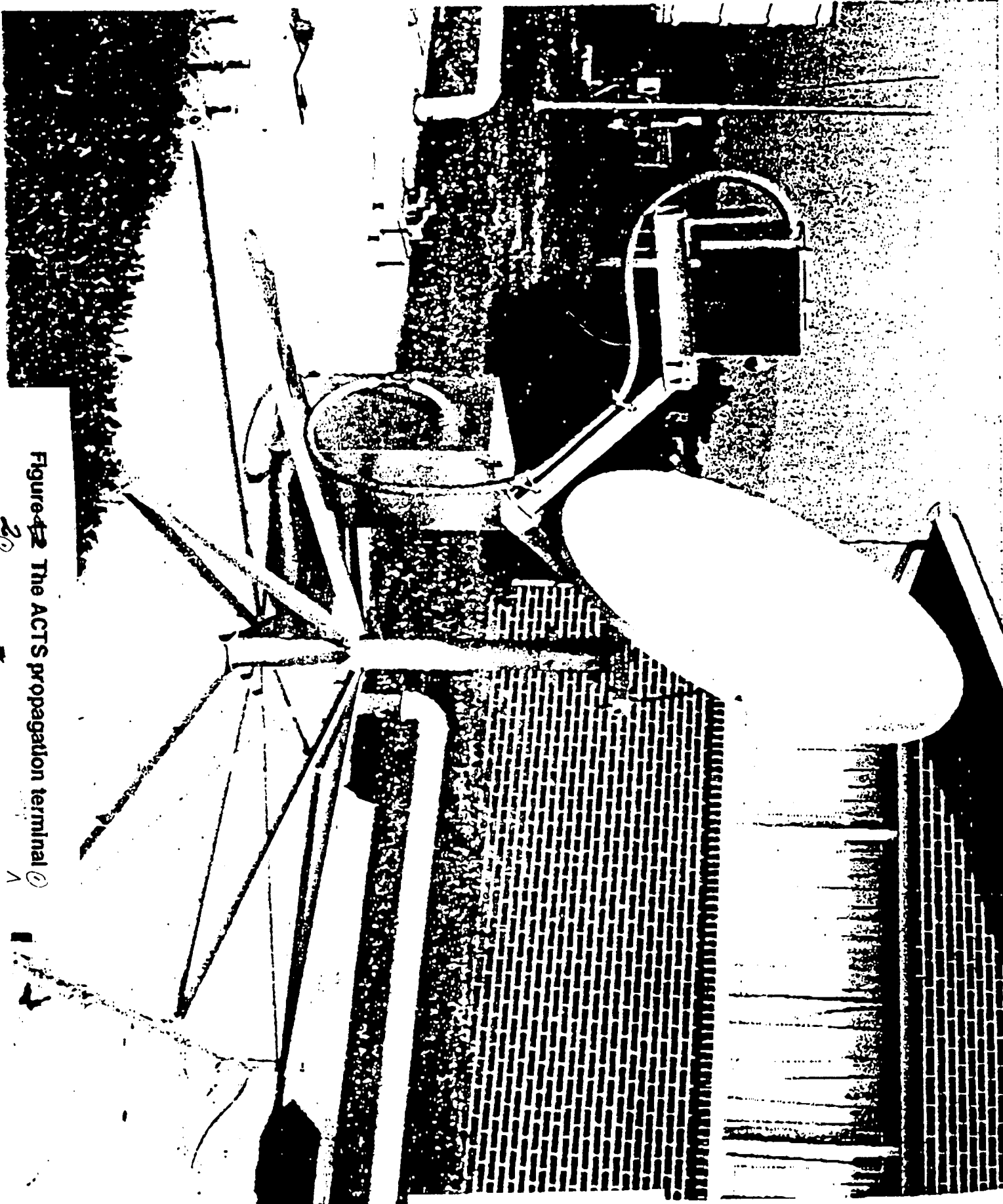**Electrical block** diagram of the ACTS propagation terminal A

Fig 2

Figure 2 The ACTS propagation terminal

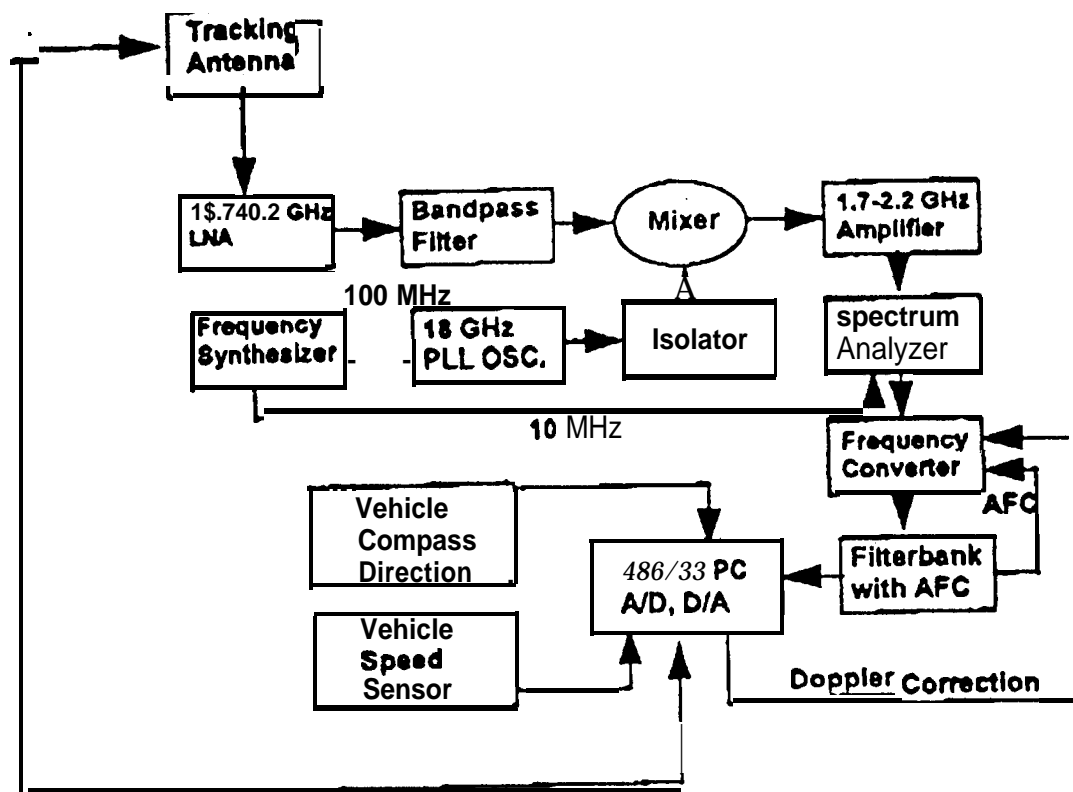Figure 2: Block diagram of mobile receiver system.

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Fig 3